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# Do job destruction shocks matter in the theory of unemployment?

Melvyn G. Coles\*,  
University of Essex

Ali Moghaddasi Kelishomi  
University of Warwick

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## Abstract

Because the data show that market tightness is not orthogonal to unemployment, this paper identifies the many empirical difficulties caused by adopting the free entry of vacancies assumption in the Diamond-Mortensen-Pissarides framework. Relaxing the free entry assumption and using SMM finds the vacancy creation process is less than infinitely elastic. Because a recession-leading job separation shock then causes vacancies to fall as unemployment increases, the ad hoc restriction to zero job separation shocks (to generate Beveridge curve dynamics) becomes redundant. In contrast to standard arguments, the calibrated model finds the job separation process drives unemployment volatility over the cycle.

This paper shows how the unemployment dynamics implied by the Diamond-Mortensen-Pissarides framework change fundamentally when the free entry of vacancies assumptions is relaxed. This is important because we show a key implication of the free entry approach - that conditional on productivity variables, market tightness is orthogonal to unemployment - is not consistent with the data. Furthermore with a less than infinitely elastic vacancy creation process, we show why a recession-leading job separation shock then

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causes vacancies to fall as unemployment increases. This dynamic response is important because an ad hoc restriction to zero job separation shocks is not then necessary to generate Beveridge curve correlations. And once an exogenous, but data-relevant, job separation process is allowed, the relaxed framework further finds it is no longer necessary to make a small surplus assumption to generate sufficient unemployment volatility; e.g. Hagedorn and Manovskii (2008), Ljungqvist and Sargent (2016). Several tests identify the much improved empirical properties of this relaxed approach relative to the free entry approach. And somewhat surprisingly, even though the calibrated model's reduced form properties are fully consistent with the Shimer (2012) decomposition of the ins-and-outs of unemployment (which seemingly suggest job separation shocks play only a minor role in explaining unemployment volatility), the structural model finds it is the job separation process which drives the large variation in unemployment over the cycle.

The seminal contribution of Mortensen and Pissarides (1994) [MP from now on] was to identify an equilibrium model of unemployment consistent with 3 claimed properties of the business cycle; (MP1) job destruction flows and job creation flows covary negatively, (MP2) job destruction flows have greater variance than job creation flows, and (MP3) job destruction patterns are asymmetric in that job destruction increases rapidly at the start of recession (also see Davis and Haltiwanger (1992), the recent survey by Elsby et al (2015) and Figures 4 and 5 below regarding the Great Recession).<sup>1</sup> Shimer (2005), of course, identifies three difficulties with the MP framework: (S1) it generates too little unemployment persistence, (S2) with an appropriately calibrated productivity process, it yields insufficient unemployment volatility and (S3) large job separation shocks generate a counterfactual positive correlation between unemployment and vacancies. Following Shimer (2005), Hall (2005) and Hagedorn and Manovskii (2008), the equilibrium unemployment literature typically assumes no aggregate job separation shocks and small surplus. Although this approach speaks to the Shimer criticisms (S1)-(S3), it is inconsistent with (MP1)-(MP3) for it implies a much larger variance of job creation flows than of job separation flows. An important aim of our paper is to identify a fully consistent approach.

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<sup>1</sup>Because we abstract from on-the-job search, our paper follows Shimer (2005) and refers instead to job separation shocks which describe the outflow of employed workers into unemployment. Job destruction shocks are clearly related but are not the same for, with on-the-job search, a job is also destroyed when an employee quits for alternative work and the firm does not hire a replacement.

The free entry of vacancies assumption is very strong for it implies a penny increase in productivity causes an instantaneous jump in the number of vacancies.<sup>2</sup> Instead we adopt a job creation process analogous to Diamond (1982) and Fujita and Ramey (2005): creating a new job here requires an initial investment in a new technology, where the sunk cost of any such investment is considered a random draw from an exogenous distribution. This “Diamond entry” process encompasses the free entry assumption as a special case but, with a finite measure of firms and heterogeneous investment costs, it also allows a vacancy creation process which is less than infinitely elastic. Because this elasticity is central to explaining equilibrium unemployment dynamics, we use Simulated Method of Moments to identify it using target moments taken from Shimer (2005) which describe the cyclical behavior of unemployment, vacancies and market tightness. Rather than being infinitely elastic, SMM instead finds the vacancy creation process is inelastic. This has important consequences. For example unlike the free entry case, a steep increase in unemployment does not generate a correspondingly steep increase in vacancies. Indeed an inelastic vacancy creation process generates the added unemployment persistence which is otherwise missing in the free entry approach; a more muted vacancy creation response to higher unemployment implies lower job finding rates and thus more persistent unemployment. It also fundamentally changes the impulse response of the economy to a job separation shock.

With free entry, large job separation shocks generate a counter-factual positive correlation between unemployment and vacancies; e.g. Shimer (2005). This is not the case with Diamond entry. Following a single job separation shock, the calibrated model finds the stock of vacancies falls because over-sampling by the pulse of laid-off workers depletes the existing vacancy stock. An inelastic vacancy creation process and a positively autocorrelated job separation process then generate an increasing unemployment stock, a declining vacancy stock which together imply worker job finding rates plummet. We show these unemployment dynamics, following a recessionary job separation shock, are fully consistent with the insights of Shimer (2005), (2012). But equally importantly, the approach is also consistent with (MP1)-(MP3) and the U.S. unemployment dynamics which followed the Great Recession.

The paper is structured as follows. Section 2 describes the model and

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<sup>2</sup>Free entry implies vacancies exhibit high frequency variations which is also inconsistent with the data; e.g. Snickers (2016).

section 3 characterises its (Markov) equilibrium. Section 4 describes the calibration exercise and considers various tests which compare the model’s properties to the properties of the free entry/small surplus/no job separation shocks approach (also see Elsby et al (2015) for a different test which supports our approach). Section 5 examines the role played by the job separation process in explaining unemployment volatility and section 6 uses the calibrated model to consider the impact of the Great Recession on US labour market outcomes but using layoffs [taken from JOLTS] as the measure of job separation shocks. Section 7 concludes and section 8 contains the Data Appendix.

## 1 Model

We use a conventional equilibrium unemployment framework with discrete time and an infinite time horizon; e.g. Pissarides (2000). All firms and all workers are equally productive, all firms pay the same (Nash bargained) wage, each worker-firm match survives until it is hit by a job separation shock. The only difference is that vacancies evolve as a stock variable with a less than infinitely elastic vacancy creation process. Without free entry the stocks of unemployment and vacancies become relevant aggregate state variables.

There is a finite, fixed measure  $F > 0$  of firms who create vacancies. In every period, each firm has one new (independent) “business opportunity”. Given that opportunity, the firm compares its investment cost  $x$  against its expected return. Its expected return depends on the state of the aggregate economy at time  $t$ , denoted  $\Omega_t$  which is described in detail below. We let  $J_t = J(\Omega_t)$  denote the expected return of a business opportunity in state  $\Omega_t$ . The investment cost  $x$  is an idiosyncratic random draw from an exogenous cost distribution  $H$ . For tractability we assume this investment cost captures all of the idiosyncratic features associated with any given business venture - in other words, highly profitable opportunities correspond to low realised values of  $x$ . Should the firm decide to invest, it pays the sunk cost  $x$  and then holds an unfilled job with expected value  $J_t$ ; i.e. each new investment generates one new vacancy.

Following Diamond (1982), each firm invests in its business opportunity if and only if it has positive value; i.e. when  $x \leq J_t$ . This requires no recall of a business opportunity should the firm not immediately invest in it. As

investment occurs whenever  $x \leq J_t$  then, at the aggregate level,  $i_t = FH(J_t)$  describes total period  $t$  new vacancy creation.

To describe how a firm fills a vacancy, we adopt the standard matching framework (but without free entry). There is a unit measure of infinitely lived workers. All workers and firms are risk neutral and have the same discount factor  $0 < \beta < 1$ . Workers switch between being employed and unemployed depending on their realised labour market outcomes.  $c \geq 0$  describes the per period cost of posting an unfilled vacancy.

Each period is characterised by the measure  $v_t$  of vacancies (currently unfilled jobs) and the measure  $u_t$  of unemployed workers (so that  $1 - u_t$  describes the number employed). The hiring process is frictional: the measure  $m_t$  of new job-worker matches in period  $t$  is described by a matching function  $m_t = m(u_t, v_t)$ , where  $m(\cdot)$  is positive, increasing, concave and homogenous of degree one.

While unemployed a job seeker enjoys per period payoff  $z > 0$ . In period  $t$ , each job-worker match produces the same market output  $p = p_t$ , where aggregate productivity  $p_t$  evolves according to an exogenous AR1 process (described below). Job separations are also an exogenous, stochastic process where  $\delta_t$  describes the probability that any given job, either filled or unfilled, is destroyed. In the event of a filled job being destroyed, the worker separates from the firm and becomes unemployed, while the job's continuation payoff is zero.

We next describe the sequence of events within each period  $t$ . Each period has 5 stages:

**Stage I [new realisations]:** given  $(p_{t-1}, \delta_{t-1})$  from the previous period, new values of  $p_t, \delta_t$  are realised according to

$$\begin{aligned} \ln p_t &= \rho_p \ln p_{t-1} + \varepsilon_t \\ \ln \delta_t &= \rho_\delta \ln \delta_{t-1} + (1 - \rho_\delta) \ln \bar{\delta} + \eta_t \end{aligned}$$

where  $(\varepsilon_t, \eta_t)$  are white noise innovations drawn from the Normal distribution with mean zero, covariance matrix  $\Sigma$ ,  $\bar{\delta} > 0$  is the long-run average job separation rate while long-run productivity  $p$  is normalised to one;

**Stage II [bargaining and production]:** the wage  $w_t$  is determined by Nash bargaining. Production takes place so that a job match yields one period profit  $p_t - w_t$  while the employed worker enjoys payoff  $w_t$ . Each unemployed worker enjoys payoff  $z$ ;

**Stage III [vacancy investment]:** firms invest in new vacancies  $i_t$ ;

**Stage IV [matching]:** let  $u_t, v_t$  denote the stock of unemployed job seekers and vacancies at the start of this stage. Matching takes place so that  $m_t = m(u_t, v_t)$  describes the total number of new matches;

**Stage V [job separation]:** each vacancy and each filled job is independently destroyed with probability  $\delta_t$ .

## 2 Markov Dynamics and Equilibrium.

This section describes the (Markov) equilibrium dynamics. Because  $u_t$  is defined as the number unemployed in period  $t$  immediately prior to the matching stage (stage IV), then  $u_t$  evolves according to:

$$u_t = u_{t-1} + \delta_{t-1}(1 - u_{t-1}) - (1 - \delta_{t-1})m_{t-1} \quad (1)$$

where  $m_{t-1} = m(u_{t-1}, v_{t-1})$ . The second term describes the stock of employed workers in period  $t - 1$  who become unemployed through a job separation shock. The last term describes the match outflow where such matches are also subject to the period  $t - 1$  job separation shock.

The vacancy stock dynamics are given by

$$v_t = (1 - \delta_{t-1})[v_{t-1} - m_{t-1}] + i_t, \quad (2)$$

where the first term describes those vacancies which survive (unfilled) from the previous matching event, while  $i_t$  describes new vacancy creation.

To determine equilibrium new vacancy creation  $i_t$  we restrict attention to Markov equilibria. Once  $(p_t, \delta_t)$  are realised, define the intermediate stock of vacancies

$$\tilde{v}_t = (1 - \delta_{t-1})[v_{t-1} - m_{t-1}]$$

which is the number of surviving vacancies carried over from the previous matching event. When bargaining occurs in stage II, let  $\Omega_t = \{p_t, \delta_t, u_t, \tilde{v}_t\}$  denote the corresponding state space. As described below, any standard Nash bargaining procedure yields a wage rule of the form  $w_t = w^N(\Omega_t)$ . Stage III then determines optimal investment  $i_t = i(\Omega_t)$ . As the matching and separation dynamics ensure  $\Omega_t$  evolves as a first order Markov process, then  $\Omega_t$  is indeed a sufficient statistic for optimal decision making in period  $t$ .

We next characterise the Bellman equations describing optimal behaviour. In period  $t$  and at the start of stage II with state vector  $\Omega_t$  (i.e. prior to production and matching but after new  $p_t, \delta_t$  have been realised) let:

$J_t = J(\Omega_t)$  denote the expected value of a vacancy;  
 $J_t^F = J^F(\Omega_t)$  denote the expected value of a filled job;  
 $V_t^U = V^U(\Omega_t)$  denote the worker's expected value of unemployment;  
 $V_t^E = V^E(\Omega_t)$  denote the worker's expected value of employment.

Let  $E[\cdot|\Omega_t]$  denote the expectations operator given period  $t$  state vector  $\Omega_t$ . The timing of the model implies the value functions  $J_t, J_t^F$  are defined recursively by:

$$J_t = -c + \beta(1 - \delta_t)E \left\{ \frac{m(u_t, v_t)}{v_t} J_{t+1}^F + \left[1 - \frac{m(u_t, v_t)}{v_t}\right] J_{t+1} | \Omega_t \right\} \quad (3)$$

$$J_t^F = p_t - w_t + \beta(1 - \delta_t)E \{ J_{t+1}^F | \Omega_t \}. \quad (4)$$

The worker value functions are also defined recursively:

$$V_t^U = z + \beta E \left[ V_{t+1}^U + (1 - \delta_t) \frac{m(u_t, v_t)}{u_t} [V_{t+1}^E - V_{t+1}^U] | \Omega_t \right] \quad (5)$$

$$V_t^E = w_t + \beta E [V_{t+1}^E + \delta_{t+1} [V_{t+1}^U - V_{t+1}^E] | \Omega_t]. \quad (6)$$

Because firms invest if and only if the business opportunity has cost  $x \leq J_t$ , equilibrium new vacancy creation  $i_t = i(\Omega_t)$  where

$$i_t = FH(J_t), \quad (7)$$

and  $J_t = J(\Omega_t)$ .

Assuming workers have bargaining power  $\phi \in [0, 1]$ , the axiomatic Nash bargaining approach closes the model with

$$(1 - \phi) [V_t^E - V_t^U] = \phi [J_t - J_t^F].$$

Using the above equations, this condition determines the equilibrium wage  $w_t = w(\Omega_t)$ . The above thus yields a system of autonomous, first order difference equations determining (i) the evolution of  $\Omega_t$  and (ii) the equilibrium value functions with corresponding investment rule  $i_t = i(\Omega_t)$ .



### 3 Calibration and Tests.

The following calibrates the model to the data considered in Shimer (2005). As the framework is so standard, we adopt the calibration parameters as described in Mortensen and Nagypal (2007). Specifically we assume each period corresponds to one month and a standard Cobb-Douglas matching function  $m = Au^\gamma v^{1-\gamma}$ . Table 1 describes the corresponding Mortensen/Nagypal parameter values.

Table 1: Mortensen/Nagypal Parameters

Parameter		Value
$\gamma$	elasticity parameter on matching function	0.6
$\phi$	worker bargaining power	0.6
$z$	outside value of leisure	0.7
$\beta$	monthly discount factor	0.9967

Note the Hosios condition is satisfied. As the productivity process for  $p_t$  implies its (long run) mean value equals one, surplus  $(1 - z)/z = 43\%$  is large. The monthly discount factor implies an annual discount rate of 4%.

Rather than impose zero job separation shocks, we calibrate the  $\{p_t, \delta_t\}$  process to the data described in Shimer (2005). Figure 1 describes the magnitude of log-deviations in (i) job separation rates and (ii) labor productivity as computed for the Shimer (2005) data at business cycle frequencies.<sup>3</sup>

As these data are only recorded quarterly while the model adopts a monthly time structure, we choose the autocorrelation parameters  $\rho_p$ ,  $\rho_\delta$  and covariance matrix  $\Sigma$  so that the implied process  $(p_t, \delta_t)$ , when reported at quarterly intervals, matches the first order autocorrelation and cross correlation implied by the data. Doing this yields:

As demonstrated in Figure 1 and consistent with the view expressed in MP, the job separation innovations are strongly negatively correlated with productivity innovations and have much greater variance. Of course MP described an endogenous job destruction margin and a single exogenous stochastic process for  $\{p_t\}$ .

When calibrating a DMP framework, it is often found the vacancy posting cost  $c$  must be large. This is typically explained by arguing it reflects

<sup>3</sup>The Data Appendix describes how Shimer (2005) measures the job separation rate.

<sup>4</sup>Both series are in logs as deviations from a HP trend with smoothing parameter  $10^5$

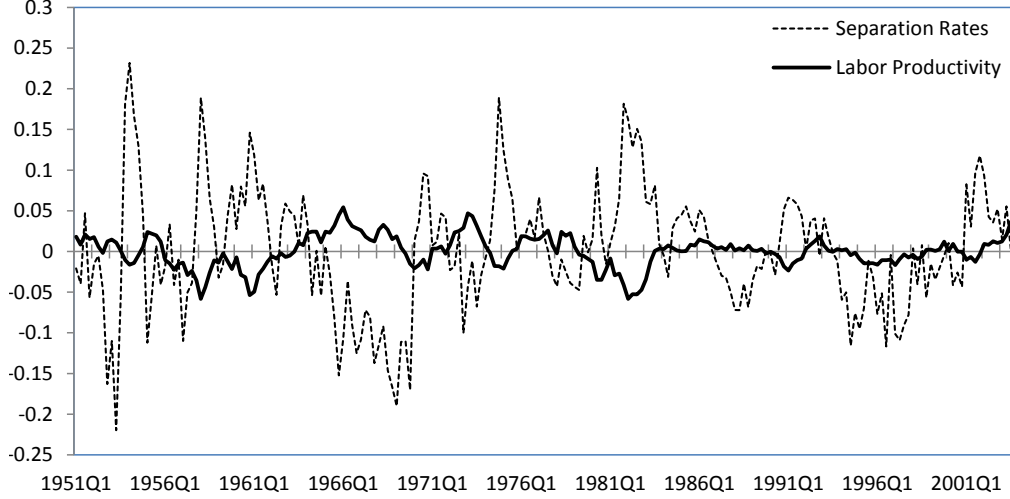


Figure 1: U.S. Separation Rates and Labor Productivity [1951-2003]<sup>4</sup>

Table 2:  $(p_t, \delta_t)$  Stochastic Process [Monthly Frequencies]

Parameter			Value
$\rho_p$	productivity autocorrelation		0.965
$\rho_\delta$	separation autocorrelation		0.875
$\sigma_p$	st. dev. productivity shocks		0.0070
$\sigma_\delta$	st. dev. separation shocks		0.042
$\rho_{p\delta}$	cross correlation		-0.63

previously sunk job creation investments. Here we take the converse case: we instead presume small vacancy posting costs ( $c = 0$ ) and so all job creation costs are tied to the ex-ante investment decision. Given the vacancy creation rule implies  $i_t = FH(J_t)$ , we adopt the simplest, most parsimonious functional form

$$i_t = F J_t^\xi \quad (8)$$

so that  $\xi$  describes the elasticity of new vacancy creation with respect to vacancy value.  $\xi = \infty$  describes infinitely elastic new vacancy creation (analogous to the free entry case) while  $\xi = 0$  implies perfectly inelastic (fixed) new vacancy creation.

The framework is calibrated to fit the long run turnover means. To ensure

comparability of results, we follow Shimer (2005) who argues that (i) the mean job separation probability should equal 3.4% per month, (ii) the average duration of an unemployment spell is 2.2 months and thus the long run unemployment rate equals  $u = 7\%$ . We also note the average duration of vacancies is around 3 weeks (Blanchard and Diamond (1989)). The first restriction ties down  $\bar{\delta} = 0.034$  [mean monthly job separation]. Depending on the choice of  $\xi$ , the latter two restrictions tie down  $A$  [the scale parameter on the matching function] and  $F$  [the scale parameter on the vacancy creation rule]. For example the choice  $\xi = 1$  [the distribution of investment costs is uniform] requires  $A = 0.594$  and  $F = 0.0075$ .

This leaves us with one free parameter  $\xi$ , the elasticity of the job creation process. We estimate  $\xi$  using simulated method of moments as described in Ruge-Murcia (2012) with a Newey-West diagonal weighting matrix. For each chosen value  $\xi$  we first update parameter values  $(A, F)$  so the generated data is consistent with the long run turnover means. The target moments used to identify  $\xi$  are the standard deviations and correlations of unemployment, vacancies and market tightness taken from Table 1 in Shimer (2005).

### 3.1 Results

Column 1 [labelled Data] in Table 3 records the data targets, where the Beveridge curve (BC) describes the negative correlation of vacancies with unemployment. The remaining columns describe the corresponding statistics using model generated data.

We begin with the final column, labelled H/M. This column instead assumes free entry, sets  $z = 0.955$  (small surplus),  $\phi = 0.052$  (low worker bargaining power),  $\delta_t = \bar{\delta}$  (no separation shocks) as considered in Hagedorn and Manovskii (2008).<sup>5</sup> This specification yields the Beveridge curve [BC] and good volatility outcomes. The column “H/M with JD” augments the H/M specification with the above job separation process (and  $c$  appropriately recalibrated). Adding separation shocks yields greater unemployment volatility but, consistent with the arguments in Shimer (2005), reduces the strong negative correlation between unemployment and vacancies.<sup>6</sup>

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<sup>5</sup>For comparability of results we otherwise retain the Mortensen/Nagypal parameter values, set  $x = 0$  and calibrate  $c$  to fit the same long run turnover means. Doing this implies  $c = 0.63$ . Hagedorn and Manovskii (2008) instead specify  $\gamma = 0.41$ ,  $\bar{\delta} = 0.026$ ,  $c = 0.58$ .

<sup>6</sup>Fujita and Ramey (2012) also make this point and consider the role of on-the-job

Table 3: Simulation Results

	Data	$\xi = 0.265$	$\xi = 1$	H/M with JD	H/M
<b>Standard Deviations</b>					
$\sigma_u$	0.19	0.18	0.15	0.19	0.14
$\sigma_v$	0.20	0.20	0.14	0.24	0.27
$\sigma_\theta$	0.38	0.38	0.28	0.40	0.40
<b>Cross Correlations</b>					
$\text{corr}(v, u)$ [BC]	-0.89	-0.96	-0.93	-0.76	-0.87
$\text{corr}(\theta, u)$	-0.97	-0.99	-0.99	-0.92	-0.95
$\text{corr}(\theta, v)$	0.98	0.99	0.98	0.95	0.99

Notes:  $\sigma_x$  is the standard deviation of  $x$ , and  $\text{corr}(x, y)$ , the cross correlation between  $x$  and  $y$ . Column 2 contains the quarterly moments from Shimer(2005)'s table 1. Column 3 are the statistics from the estimated model. Column 4, simulated model with  $\xi = 1$ , column 5, free entry model with H/M calibration with separation shocks, and the last column, H/M calibration without separation shocks. To calculate the quarterly moments, models are first simulated at monthly frequency, and then aggregated.

The  $\xi = 1$  column describes the results when the vacancy creation process is assumed unit elastic. For that choice, the model generates the right correlated behaviour but there is too little volatility. To fit the volatility targets, SMM infers the vacancy creation process must be less than unit elastic, where estimated  $\xi = 0.265$ . Although  $\xi = 0.265$  slightly overstates the negative correlation of unemployment and vacancies, the fit to the chosen targets is otherwise perfect.

We now consider 3 tests which identify the very different dynamic properties of our relaxed approach relative to the free entry case. Section 6 uses those insights to consider the dynamics of unemployment following the Great Recession. The Data Appendix reports the full set of data moments [corresponding to Table 1, Shimer (2005)] and the corresponding table for the case  $\xi = 0.265$ . Importantly for what follows, note Table 1, Shimer (2005) finds that market tightness has an exceptionally high raw correlation of -0.97 with unemployment (also see Table 3), while the raw correlation of market tightness with productivity is only 0.40 and with job separation rates it is

search in mitigating this problem.

-0.71.

### 3.2 Test 1: Market Tightness Dynamics

Market tightness  $\theta_t = V_t/U_t$  determines how worker job finding rates vary over the cycle. The free entry approach yields a particularly useful simplification: that equilibrium market tightness  $\theta_t = \theta^*(p_t, \delta_t)$  is independent of unemployment  $U_t$ . But conditional on  $(p_t, \delta_t)$ , an obvious statistical test is whether market tightness  $\theta_t$  is indeed orthogonal to unemployment. We thus ask whether the model generated market tightness dynamics are consistent with the data.

Column 1 [Data] in Table 4 reports the results of estimating a reduced form, log-linear statistical relationship

$$\log \theta_t = \alpha_0 + \alpha_1 \log p_t + \alpha_2 \log \delta_t + \alpha_3 \log U_{t-1}, \quad (9)$$

on Shimer (2005) HP filtered data where, because market tightness is measured as  $V_t/U_t$ , we mitigate simultaneity issues by using last period  $U_{t-1}$  as the conditioning variable.<sup>7</sup> Estimated t-statistics are reported in brackets.

Table 4: Reduced Form Market Tightness Dynamics

Parameters	Data	$\xi = 0.265$	$\xi = 1$	H/M with JD
$\hat{\alpha}_1$ [productivity]	1.043 (1.98)	0.96 (80.0)	2.07 (188)	20.0 (2535)
$\hat{\alpha}_2$ [JD $\delta_t$ ]	-1.66 (-10.4)	-0.65 (-240)	-0.51 (196)	-0.26 (-180)
$\hat{\alpha}_3$ [unemployment]	-1.43 (-26.0)	-1.94 (-1620)	-1.56 (-1114)	-0.001 (-1.4)

Notes: Estimation results of reduced form equation (9), using Shimer (2005) data (column 2) and models generated data (columns 3-5). t-statistics are reported in brackets.

<sup>7</sup>using  $\log U_t$  as the conditioning variable finds estimated productivity effects ( $\hat{\alpha}_1$ ) become negative and insignificant, and there is an even stronger negative correlation between unemployment and measured market tightness.

According to the data (column 1), market tightness is positively correlated with productivity and negatively correlated with job separation rates. But productivity shocks are barely significant [a t-statistic equal to 1.98] while market tightness is very strongly (negatively) correlated with unemployment [a t-statistic equal to -26]. Figure 5 in Section 6, which graphs how market tightness evolved following the 2008 Great Recession, fully supports this view of the data. The final column [H/M with JD] reports the corresponding results for the free entry/small surplus approach, augmented with the above job separation process. This approach yields the opposite scenario: small surplus and free entry imply market tightness is almost entirely driven by productivity shocks and, conditional on  $(p_t, \delta_t)$ , market tightness is orthogonal to unemployment.

Although not a perfect match,  $\xi = 0.265$  yields parameter estimates which are broadly consistent with those identified on the data: market tightness is most highly [negatively] correlated with unemployment, though productivity and job separation shocks also play significant roles. Surprisingly given the insights that follow, the data suggest job separation shocks have an even greater impact on market tightness than that implied by the model.

### 3.3 Test 2: Serial Persistence.

An important criticism due to Shimer (2005) is that the MP framework does not generate sufficient persistence. Column 1 [Data] in Table 5 describes the serial autocorrelation of unemployment, vacancies and market tightness according to the (HP filtered) data. The remaining columns describe the corresponding parameter estimates based on model generated data.

Measured at quarterly frequencies, the implied serial persistence parameters for productivity and job separation rates are  $\rho_p = 0.88$ ,  $\rho_\delta = 0.73$  respectively. Column 1 [Data] in Table 5 reveals that unemployment, vacancies and market tightness are much more persistent processes.

H/M with JD does not generate any added unemployment persistence beyond that of the underlying productivity process. The reason is very simple: a free entry specification implies  $\theta = \theta^*(p_t, \delta_t)$  and, with no feedback from unemployment to market tightness, the small surplus assumption then implies unemployment has persistence  $\rho_u = \rho_p = 0.88$  which is too low.

With  $\xi = 0.265$ , Column 2 demonstrates the serial persistence of  $(U_t, V_t, \theta_t)$  is a near-perfect match to that implied by the data. This occurs because, as demonstrated in Table 4, market tightness is strongly, negatively correlated

Table 5: Estimated Serial Persistence [Quarterly Frequencies]

	Data	$\xi = 0.265$	$\xi = 1$	H/M with JD.
unemployment	0.94	0.95	0.93	0.88
vacancies	0.94	0.96	0.95	0.76
market tightness	0.94	0.96	0.95	0.87

Notes: The data column is the autocorrelation of unemployment, vacancies, and market tightness from Shimer(2005) table 1. The second column contains the autocorrelations of these variables from the estimated model (not targeted in estimation) and the rest are for the simulated model with  $\xi = 1$  and H/M calibration with job destruction shock.

with unemployment. Thus periods of high unemployment are characterised by below trend job finding rates which then increase the persistence of high unemployment. Of course the equilibrium degree of persistence  $\rho_u$  is an endogenous outcome which depends on the propagation mechanism implied by the model. Before examining that propagation mechanism in Section 5, we report our third test.

### 3.4 Test 3: The Ins and Outs of Unemployment.

Shimer (2012) argues that the variation in unemployment is more highly correlated with variations in worker job finding rates than with job separation rates. The argument begins by noting that steady state unemployment

$$u = \frac{\bar{x}}{\bar{x} + \bar{f}}$$

where  $\bar{x}$  is the (steady state) exit rate of employed workers into unemployment and  $\bar{f}$  the rate unemployed workers become employed. It is then argued that the unemployment proxy

$$u_t^P = \frac{x_t}{x_t + f_t},$$

where  $x_t$  is the period  $t$  exit rate and  $f_t$  the job finding rate, is a reasonable approximation for actual unemployment  $u_t$ . This proxy variable  $u_t^P$  can then be further decomposed into job separation effects (variations in  $x_t$ ) and job finding effects (variations in  $f_t$ ). For example putting  $x_t = \bar{x}$ , the sequence

$\bar{x}/(\bar{x} + f_t)$  describes the variation in  $u_t^P$  due solely to variations in  $f_t$ . Similarly  $x_t/(x_t + \bar{f})$  describes the variation in  $u_t^P$  due to variations in  $x_t$ . Shimer (2012) defines the contribution of the job finding rate to variations in unemployment as the covariance of  $u_t$  and  $\bar{x}/(\bar{x} + f_t)$  divided by the variance of  $u_t$ . Column 1, Table 1 in Shimer (2012) reports that variations in the job finding rate  $f_t$  contribute 77% of the variation in unemployment, while variations in the job separation rate  $x_t$  only contribute 24%.<sup>8</sup>

The small surplus/free entry approach is broadly consistent with this decomposition because large variations in job creation flows cause correspondingly large variations in unemployment and worker job finding rates. We now repeat the Shimer (2012) methodology on model-generated data with  $\xi = 0.265$ .<sup>9</sup> Computing those same statistics finds job finding variations,  $\bar{x}/(\bar{x} + f_t)$  contribute 77% of the unemployment variation, while job separation variations  $x_t/(x_t + \bar{f})$  contribute a slightly smaller 21%. The (reduced form) properties of the simulated data are thus fully consistent with the Shimer (2012) decomposition. Nevertheless we now show unemployment volatility in the structural model is driven by job separation shocks.

## 4 How Important are Job Separation Shocks in Explaining Unemployment Variation?

The above has established our framework not only provides an excellent fit for the volatilities, cross-correlations and persistences of market tightness, unemployment and vacancies, it is also entirely consistent with the Shimer (2012) decomposition of the ins and outs of unemployment. The interesting question then is how important are job separation shocks in explaining unemployment volatility? To answer this question we can instead assume zero job separation shocks  $\delta_t = \bar{\delta}$ , recalibrate the productivity process appropriately and re-estimate  $\xi$ . Doing this yields unemployment volatility  $\sigma_u = 0.05$  which is only a quarter of that observed in the data.<sup>10</sup> This should not be surprising because Figure 1 demonstrates that productivity shocks are small and we have not specified small surplus. But how can this DMP frame-

<sup>8</sup>see Figures 4 and 6 in Elsby et al (2009) and Table 1 in Fujita and Ramey (2009) for alternative estimates.

<sup>9</sup>with  $x_t \equiv \delta_t$  and  $f_t \equiv (1 - \delta_t)m(\theta_t)$ .

<sup>10</sup>With no separation shocks SMM maximises unemployment volatility by setting  $\xi$  arbitrarily large; i.e. it re-discovers the free entry assumption.



work, where unemployment volatility is driven by job separation shocks, be consistent with the Beveridge curve and the Shimer (2012) decomposition?

Consider Figures 2 and 3. Figure 2 describes the impulse response of unemployment to a single separation innovation at date zero (holding productivity fixed  $p_t = 1$ ). It also plots the exogenous AR1 job separation process  $\delta_t$ .

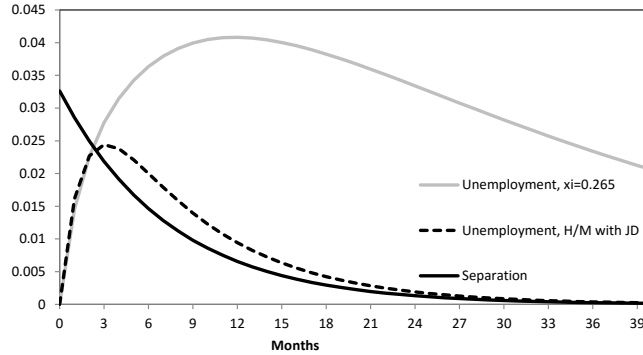


Figure 2: Impulse Response of Unemployment to a Separation Shock

The impulse response function labeled [H/M with JD] describes the impulse response of unemployment for the case of free entry and small surplus. That shock yields a relatively small increase in unemployment and unemployment exhibits the same persistence as that of the underlying separation process.  $\xi = 0.265$  instead generates a much higher unemployment peak and much greater persistence. Figure 3, which describes the corresponding impulse response of vacancies, reveals why.

Free entry with small surplus [H/M with JD] implies vacancies increase given a rise in unemployment. This vacancy response ensures unemployment quickly recovers to its long run steady state. This adjustment process also implies unemployment and vacancies covary positively which is inconsistent with the Beveridge curve.

In contrast with  $\xi = 0.265$ , Figure 3 demonstrates the vacancy stock falls as unemployment increases.<sup>11</sup> The job separation shock not only destroys some vacancies, it generates a rising tide of unemployed workers, some of

<sup>11</sup>The initial iterations in Figure 3 are affected by the assumed timing of the model. For the free entry case, a higher job separation rate  $\delta_t$  (which is known at stage I but separations do not occur till stage V) reduces stage III market tightness. Because stage

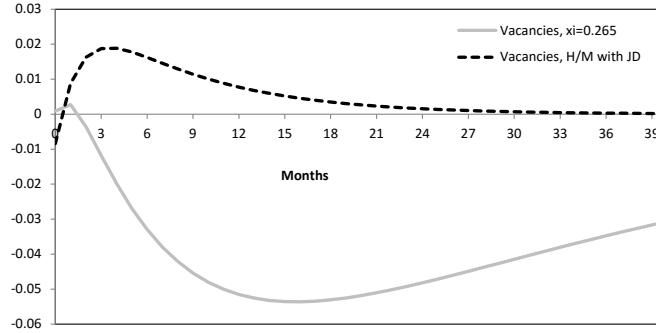


Figure 3: Impulse Response of Vacancies to a Separation Shock

whom quickly re-match with the existing vacancy stock. With an inelastic vacancy creation process, oversampling of the vacancy stock by newly laid-off workers causes the vacancy stock to fall. Unemployed worker job finding rates then plummet as the increasing number of unemployed workers pursue ever scarcer vacancies. These dynamics thus generate results consistent with Shimer (2012), the reason being that a [recession-leading but short-lived] job separation shock causes [persistently] high unemployment and [persistently] low job finding rates. And by not imposing zero job separation shocks, the calibrated model is then free to find it is the job separation process which drives unemployment volatility.

## 5 The 2008/9 Great Recession.

The power of the approach is readily demonstrated by considering the aggregate labor market dynamics of the U.S. economy following the 2008/9 Great Recession. Using CPS data, Figure 4 describes [seasonally adjusted] gross

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III unemployment is on trend for the first iteration, lower market tightness then implies vacancies fall below trend for the first iteration (but subsequently increase as unemployment increases). Conversely for the case  $\xi = 0.265$ , new vacancy creation  $i_t$  is always above trend (which ensures the unemployment stock eventually returns to trend). For the first two iterations the stock of vacancies (measured at stage III prior to job destruction) is slightly above trend. But steeply increasing unemployment and oversampling then cause the vacancy stock to plummet, where the vacancy stock begins to recover only when unemployment falls below its peak.

hires and gross job separations.<sup>12</sup> It also plots [non-farm] layoffs taken from JOLTS (a time series which has been available since 2001).

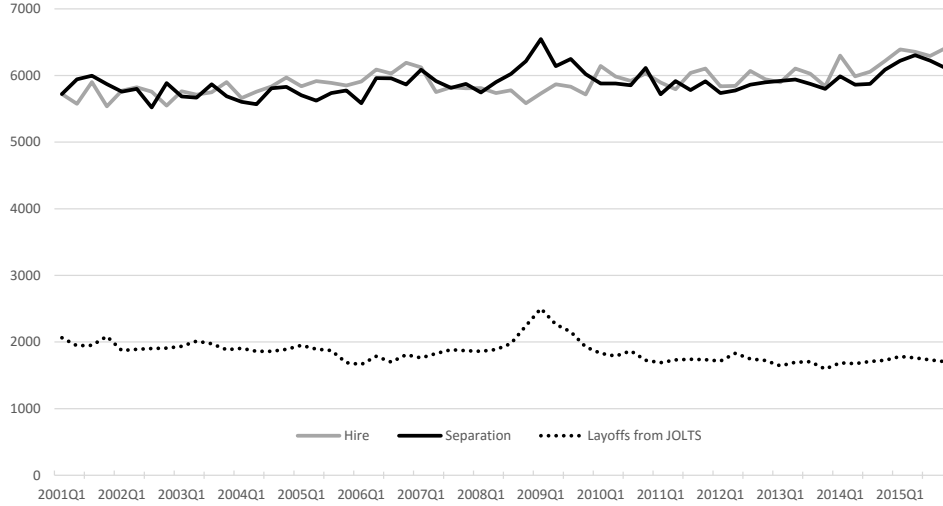


Figure 4: U.S. Job Turnover [2000-2015].<sup>13</sup>

Figure 4 reveals the unprecedentedly large spike in layoffs across the 2008-2009 Great Recession. Ceteris paribus, the free entry approach predicts vacancies increase and hires surge following such a shock. This did not happen. Instead and consistent with our approach, this demonstrably large job separation shock generated Beveridge curve dynamics: the stock of vacancies fell steeply as unemployment increased.

Figure 5 describes in greater detail the evolution of the U.S. labor market across and subsequent to the 2008/9 layoff spike. Using the Shimer (2005) methodology, it describes unemployment, market tightness, productivity and layoffs, each measured as log deviations from trend using an HP filter with smoothing parameter  $10^5$ .

<sup>12</sup>Series are constructed by the BLS from the Current Population Survey (CPS) and are available at [https://www.bls.gov/cps/cps\\_flows.htm](https://www.bls.gov/cps/cps_flows.htm)

<sup>13</sup>Hires measure is the flow of workers from unemployment and non-labor force to employment, Job Separations is the flow of workers from employment to unemployment and non-labor force (all in thousands)

<sup>14</sup>Series are quarterly deviations from HP trends ( $\lambda = 10^5$ ). Productivity is BLS output per worker from Major Sector Productivity and Costs, unemployment is BLS constructs from CPS, vacancies used in market tightness is job openings from JOLTS, and layoffs are also from JOLTS (non-farm business).

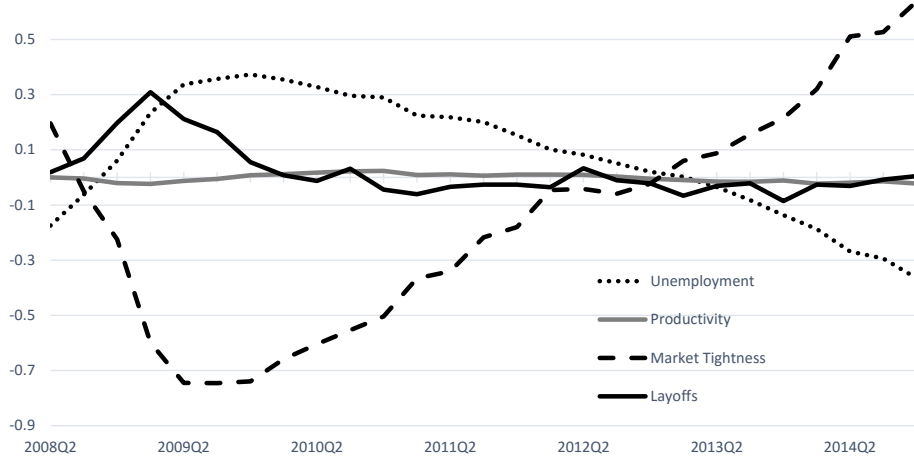


Figure 5: U.S. Labor Market Indicators [2008-2015].<sup>14</sup>

At the start of the layoff spike, market tightness was slightly above trend and unemployment slightly below. The surge in layoffs coincided with steeply increasing unemployment, a steep fall in vacancies [not graphed] and an even steeper fall in market tightness [graphed]. Yet over this time period, 2008-15, productivity was positively correlated with unemployment. Free entry and small surplus thus predict market tightness should have been positively correlated with unemployment. Consistent with Table 4, however, Figure 5 reveals that market tightness was instead strongly negatively correlated with unemployment. Furthermore with high unemployment and above trend productivity from 2010 onwards, free entry predicts the vacancy stock and gross hires should both have been well above trend. Figure 4 demonstrates hire flows merely reverted to trend. It is thus difficult to rationalise the post-2008 evolution of the U.S. economy using the free entry approach. In contrast with  $\xi = 0.265$ , the impulse response functions (Figures 2 and 3) yield qualitatively identical behavior following a job separation shock.

We identify the extent to which our framework is consistent with the data for the period 2001-2015 using the JOLTS layoff series as a more direct measure of the job separation process.<sup>15</sup> Although the 2008/9 layoff spike is not consistent with a stationary AR1 process, we repeat the above

<sup>15</sup>though it should be noted that temporary layoffs are widespread in the U.S.; e.g. Feldstein (1976) and Fujita and Moscarini (2015) .

methodology. For the period 2001-2015,  $(p_t, \delta_t)$  are assumed to follow a joint AR1 process and we reset the autocorrelation parameters  $\rho_p$ ,  $\rho_\delta$  and covariance matrix  $\Sigma$  to match the data. Doing this implies  $\rho_p = 0.95$ ,  $\rho_\delta = 0.89$  with  $\sigma_p = 0.0063$ ,  $\sigma_\delta = 0.036$  and cross-correlation  $\rho_{p\delta} = -0.38$  at monthly frequencies. Column 1 [data] in Table 6 reports the updated targets.

Table 6: Simulation Results for JOLTS calibration

	Data	$\xi = 0$	$\xi = 0.265$
<b>Standard Deviations</b>			
$\sigma_u$	0.203	0.128	0.113
$\sigma_v$	0.184	0.177	0.135
$\sigma_\theta$	0.379	0.303	0.246
<b>Cross Correlations</b>			
corr(v,u) [BC]	-0.93	-0.98	-0.97
corr( $\theta$ , $u$ )	-0.98	-0.99	-0.99
corr( $\theta$ , $v$ )	0.98	0.99	0.99

Notes: In Data column,  $u$  is the unemployment constructed by BLS from CPS,  $v$ , is the job openings from JOLTS, and  $\theta = v/u$ . The data is quarterly average over the period 2001-2015. All the statistics are calculated for HP filtered (with  $\lambda = 10^5$ ) series.  $\sigma_x$  is the standard deviation of  $x$  and  $corr(x, y)$  the cross correlation between  $x$  and  $y$ .

Column 3 records the corresponding statistics using model generated data with  $\xi = 0.265$  as previously estimated. Not surprisingly given the close match of the impulse response functions [Figures 2 and 3] to the data [Figure 5], this specification continues to provide an excellent fit of the joint correlations of unemployment, vacancies and market tightness. But this time  $\xi = 0.265$  yields too little unemployment volatility. Because a more inelastic vacancy creation process deflates job finding rates following a large layoff shock, SMM this time estimates the polar case  $\xi = 0$ ; i.e. perfectly inelastic vacancy creation rates. This in part reflects Figure 4 which shows that hires reverted to trend following the layoff spike - the so-called jobless recovery. Nevertheless even with  $\xi = 0$ , this methodology yields too little unemployment volatility over this period.

## 6 Conclusion.

This paper has revealed the empirical difficulties caused by assuming the free entry of vacancies in the DMP framework. Specifically a key implication of the free entry approach - that conditional on productivity variables, market tightness is orthogonal to unemployment - is not consistent with the data (e.g. Table 4 and Figure 5 for the Great Recession). By relaxing the free entry assumption in the DMP framework, estimation using SMM finds the vacancy creation process is instead inelastic. The resulting equilibrium framework is consistent both with the insights of Shimer (2005), (2012) and with the Mortensen and Pissarides (1994) view on job creation and job destruction (here job separation) patterns over the cycle. Results find an ad hoc restriction to zero job separation shocks is not appropriate. Indeed when suitably relaxed, this DMP framework finds it is the job separation process which drives unemployment volatility over the cycle. The approach is particularly powerful for it provides a simple and coherent explanation for the observed unemployment and vacancy dynamics in the U.S. following the Great Recession.

Our approach suggests very different lines for future research. For example, what are the underlying economic factors which drive the job separation process? Mortensen and Pissarides (1994) identify a mechanism whereby adverse aggregate productivity shocks cause pulses of job destruction. The Great Recession, however, suggests financial [or credit] shocks might also play an important role; e.g. Jermann and Quadrini (2012), Chodorow-Reich (2014), Boeri et al (2015). For example Bentolila et al (2015) show (for Spain) that firms with credit relationships tied to banks facing severe liquidity problems were much more likely to downsize or go out of business. Because the vacancy creation elasticity  $\xi$  plays a central role in determining the propagation properties of the economy, more direct evidence on its value is clearly desirable. Of course a major advantage of dropping the small surplus assumption is that the equilibrium DMP framework once more becomes relevant for policy analysis; e.g. Costain and Reiter (2008).

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## A Job Separation Measures

Given data on employment  $e_t$  (the number employed in month  $t$ ), short term unemployment  $u_t^0$  (the number of workers unemployed with duration less than one month) and an estimate of worker job finding rate  $f_t$ , Shimer (2005) infers the job separation rate  $s_t$  using

$$u_{t+1}^0 = s_t e_t \left(1 - \frac{1}{2} f_t\right).$$

With the identifying assumption that  $f_t, s_t$  are constant within the month as first considered in Gregg and Petrongolo (2005), Shimer (2012) instead notes the condition

$$u_{t+1} = \frac{(1 - e^{-f_t - s_t}) s_t}{f_t + s_t} (u_t + e_t) + e^{-f_t - s_t} u_t$$

can be used to infer  $s_t$ . Elsby et al (2009), Fujita and Ramey (2009) consider alternative approaches to measure  $s_t$ .

## B Complete Results

We report table 1 in Shimer (2005) and, for comparison, the equivalent table for our SMM results with  $\xi = 0.265$ .

Table 7: Summary Statistics, Quarterly U.S. data, 1951003, table from Shimer (2005) page 28.

	$u$	$v$	$v/u$	$f$	$s$	$p$
Standard Deviations	0.190	0.202	0.382	0.118	0.075	0.020
Quarterly autocorrelation	0.936	0.940	0.941	0.908	0.733	0.878
Correlation matrix	$u$	1	-0.894	-0.971	-0.949	0.709
	$v$		1	0.975	0.897	-0.684
	$v/u$			1	0.948	-0.715
	$f$				1	-0.574
	$s$					1
	$p$					

Table 8: SMM results with  $\xi = 0.265$

	$u$	$v$	$v/u$	$f$	$s$	$p$
Standard Deviations	0.18	0.20	0.38	0.15	0.075	0.020
Quarterly autocorrelation	0.95	0.96	0.96	0.96	0.73	0.87
Correlation matrix	$u$	1	-0.96	-0.99	-0.99	0.54
	$v$		1	0.99	0.99	-0.30
	$v/u$			1	0.99	-0.42
	$f$				1	-0.42
	$s$					1
	$p$					